SCIENCE

NEW YORK, JULY 24, 1891.

MUSEUMS AND THEIR PURPOSES.[1]

I HAVE to thank the secretary and curator of this academy for the opportunity to state publicly some thoughts which have been uppermost frequently in my mind during several years past, but which I have never had occasion to put into form. In the North-west, educational methods and institutions are yet in their formative stages. This is still more the case with scientific education and scientific institutions. But we are fast laying foundations for posterity to build upon, which we ought to plan with a far-reaching vision into the future. Our mistakes, if we make them, will be forever laid at our door; and our children and our children's children will condemn or approve of us and our labor in accordance with the degree of fitness that they find between the foundations that we lay and the superstructure which they may have to build thereon.

It is because I think I can see in the future of scientific work in Minnesota some glimpses of the outlines of that superstructure, that I wish to call your attention to some of the fundamental essentials that ought to enter into the foundation which we are called upon to lay. Minnesota is an empire, territorially of itself, and it will become the "empire state" of the North-west, politically, educationally, and financially, and it ought to become the leader in the North-west in scientific enterprise and organization. In this organization of scientific work in the State, the museums will play no inconspicuous part. It will be safe to say that at those centres where the museums are located will be found in greatest efficiency all the other scientific agencies, whether of laboratories, libraries, or lectureships. There is a fitness in their association, almost an invincible bond of attraction, which will ultimately overthrow all the accidental or artificial devices which, in our possible short-sightedness, we may throw about them to keep them asunder.

A museum was originally a temple in which the muses were worshipped or invoked. At Athens, a hill near the Acropolis was called the Museum because of the existence on it of such a temple. It was a place for study and high contemplation. Although we have outgrown the mythology of the Greeks, their literature and their institutions have so pervaded our language and institutions that we find the germs of some of our choicest civil and social growths sunk deep into that old civilization. Those germs have fruited, in part, in our day, and the fruit is somewhat different from what the germs seemed to foreshadow. The germ of the museum at Athens, fraught then with prophecy of poetry, art, and history, had but little promise of science. The muse of astronomy was but one of the nine whose shrines were in those temples. Scholars who sought the museum were inspired with visions of the beautiful and the poetic, or of the light and passionate frivolities of life. There was no muse of geology known, though that science, by her aid, was to be a potent factor in preserving and perpetuating the words "muse" and "museum" in the new civilization; nor any muse of biology, though the poetry of biologic science has since been a prolific branch of modern scientific literature. There was no muse of botany, nor of paleontology, nor of electricity. I think that if the Grecian Museum had continued to the present, the number of the inspiring muses would have been increased far beyond the mythical nine. That dynasty has passed away, and with it has almost been lost the original idea of the museum.

The word, however, which is imperishably stamped on the language of all modern civilized nations, remains. It bears a weird, and to the original nine who gave it origin and character and authenticity, almost an unknown signification. Let us look into this a moment, and endeavor to learn what is the modern meaning of this word "museum." We shall find that it bears three interpretations, or dominant ideas. First, there are museums designed for entertainment; second, there are museums intended for the instruction of the visitor; third, there are museums for research.

The modern so-called "dime museum" typifies the museum designed for entertainment, although in many such may be found some of the characteristics of the second class. It is a place of "curos'ties" and monstrosities, of cheap theatricals and legerdemain. Such have long been known, although under different names, in the principal cities of Europe and America, the most noted in this country being Barnum's Museum in New York City thirty-five or forty years ago. Here the visitor is wholly passive under the manipulation of the presiding genius of the place. He may enter the presence with any foreign, or even adverse sentiment. He simply is willing to be amused for half an hour.

The modern museum designed for instruction has a somewhat higher function and rank. Its purpose is to inspire in the visitor a thirst for knowledge, and in a degree to furnish that knowledge, at second hand. He seeks not that amusement may be lavished upon him, but he is at least willing to put forth an effort to obtain information. With this end attained he is satisfied. The instruction he has received remains in his mind unclassified and generally unassimilable. He knows more of the earth and of the things upon it when he retires from the place than when he approached it. Of his mental capacities his memory only is necessary thereafter to enable him to make useful that which he has seen. He is instructed and benefitted in so far as he appreciates and retains the ideas which the various objects have brought to his mind. Such museums are common. They accompany nearly all modern institutions of higher learning. They are patronized in proportion to the number of instructive objects they have on exhibition, or the variety and beauty of their specimens, or of the cases in which they may be contained. They serve, like travelling circuses, to attract the light-minded and the curious; but their service is higher than that of the circus, in the higher grade of information which they impart, and in the greater benevolence of the motive for which they are maintained. Such museums discharge an important function in education, and particularly in scientific education, and to this day they express the popular idea of a perfect museum. They may sometimes partake of the elements that characterize the third class, or the museum for research, and, in so far as they do, their sphere is raised nearer the true ideal. In general, however, they are far removed from the true museum, and from the germinal idea which was planted in the Grecian mind. You will note that the motive of the patron in both these cases is one of self-improvement or gratification. He has no object ulterior to that of being himself benefitted. There is, moreover, in the museum itself, no other purpose expressed, nor any possibility of any other purpose being accomplished by the visitor.

These appendages to the science departments of our colleges are considered desirable and even necessary. In the curriculum, however, for making scholars, and for rendering students capable in their turn of teaching other students, or in making well-informed, self-reliant scientists, they serve but as subordinate agencies. They do not answer to the ends of scientific instruction in that degree that is demanded by the scientific advancement of our day, nor in that degree with which the ways and means of classical instruction at this day answer to the classical learning of our day. The classical student, even when he begins the classics, is brought into immediate and personal contact with the thing which he studies. The problems presented to him,

[1] A lecture delivered before the Academy of Sciences of St. Paul, Minn., by Professor N. H. Winchell, State geologist.

require him to investigate the principles of the language for himself to the best of his ability, and the preceptor comes to his aid only when his translation is so faulty as to require correction. He is constantly at his wits' ends to discover the ideas hidden in the text before him. In those institutions, however, which are endowed with these exhibition museums, the scientific instruction is not usually a requirement to study the subjects by original investigation, but a requirement to read, listen, absorb, recite. It is an instruction on a parallel with early childhood. It is an inpouring process of imparting information. It is not by any means on a par with that instruction which everywhere is given the classical student. One imparts enlightenment, and the other mental strength and culture. There is justice in the claim set up for the study of the classics in such cases, viz., that they furnish a better mental training and culture. How much of this claim, which is common only among those who have never had a scientific training in the scientific method, is due to the prevalence of this kind of scientific teaching in our colleges, would be an interesting and fruitful inquiry, if thoroughly investigated.

Suppose, on the other hand, that scientific instruction were as thoroughly organized in all the colleges of the country as is that of Greek and Latin. Suppose on the analytic, or on the inductive method, all scientific truth were imparted to the student. This would, of course, be impossible in the ordinary undergraduate course without disturbing the present *status*, in which only mathematics and the classics are thus taught. Suppose the student were shown a list of scientific problems which he must solve, with only the guidance of his native resources, and a few hints from his instructor as to the principles involved. Then let another series be presented, which, while involving those already answered, should demand still further and wider investigation. Suppose a whole term be spent in that way; nay, let us suppose a whole year, yes, three or four years, and, in order to make a parallel case, let us require that before presenting himself for admission to the freshman class the student shall have spent a year or two in similar independent investigation within the preparatory school. Then let it be further supposed that this method of scientific instruction were well established, with competent instructors in all the colleges of the country, with a public sentiment sufficiently informed to sustain it, and that it had courses of study well organized and differentiated, leading to honorable degrees at graduation, and public emoluments inviting to its pursuit, — then, and only then, could the disciplinary value of scientific education be compared fairly with that of the classics.

You may see at once that an exhibition-museum, as an attachment to an institution dominated by the old ideas of education, is only expressive of the kind of scientific education which such an institution desires to impart. It is only the sign of the enslavement of the scientific idea, in all its educational machinery, by the classical. To my mind, the establishment of such a museum would not be the best way to introduce scientific instruction into any college, however successful it might be in touching the popular appreciation or in opening the popular purse. The best scientific instruction is based on other foundations, and pursues other methods, and reaches other ends.

The true museum is that which approaches nearest to the cardinal idea of the Grecian museum. Its aim is not to amuse, nor to instruct, but to afford that inspiration which shall enable the visitor to instruct others. The reverent devotee approaches such a museum with no selfish motive. He invokes his muse to inspire in him sentiments that shall benefit his fellow-men. When I say that there are but few such museums in our day, you will not question the statement. You will rather inquire whether there are any such in existence. Such a museum is based on a broader idea than the exhibition-museum, although its frequenters may be fewer. Scientific research, long-continued study, profound contemplation, and conference with the writings of others — these are the purposes of such a museum. In but few places is this carried out, but it is the fundamental and growing idea underlying some modern museums. The full fruition of this idea will be the culminating result of the germ which was planted in the early Grecian soil. Transferred to modern times, ripening in the sunlight of a new civilization, with its roots nourished by more genial influences, the germ of the Grecian museum produces in our day, or is beginning to produce, a fruit somewhat different, although generically it is identical with that which it bore under Athenian culture.

Modern society is beginning to awaken to the debt that it owes to modern science. Modern science is the savior and promoter of modern institutions, the generator and sustainer of modern civilization. I speak not of the influence of the Christian church in modern times, because the Christian church cannot be accredited with the revival of modern science, nor with the inauguration of modern civilization. The Christian church existed through the darkest epochs of the middle ages, and gave no aid to science. Modern science, which, in its ramifications into social affairs, is the distinguishing badge of modern civilization, rose in spite of the church, and against its active opposition. This is not the fault of Christianity but the fault of those who were responsible for misrepresenting Christianity. The germinal motive of the Grecian museum — the search after truth and the desire to be inspired by it — was also the germinal idea of Christianity. Its fruition is the effort to serve and to save others. Many generations passed during which the germ slumbered, or was smothered under the tares of human ambition and sophistry. At length it pierced through the adversities by which it was surrounded, and began to manifest itself by its good works, and by the good which it reflected upon its enemies. The church was the nominal custodian of the germ, and ought to have welcomed and enjoyed its first fruits; but it did not. The sturdy growth which it now presents to modern society has reacted upon the church, and the church begins to recognize what a nearly fatal mistake she made in trying to smother the young plant. She now perceives that the plant is very similar to her own, and that the fruits of the two are nearly identical. Whereas she had discarded it, at its first appearance, as a vicious and foreign weed, she now is willing that it shall be transplanted into her own field and shall be nurtured by the same hands.

It is only with this recent awakening of modern society to the usefulness and beneficence of modern science that the true idea of a true museum has become again apparent. This idea finds illustration in a few museums in all the great nations of Europe and America. The highest enlightenment is compatible with the highest efficiency of these organizations, for they are the great dynamos that keep the machinery of modern advancement continually moving. This, however, has been the result of a growth whose former stages were insignificant, and perhaps but faintly foreshadowed the form that the completed museum should take on. This growth had a natural philosophical as well as chronologic order. We might appeal to history to show this. From the lowest form of a museum meant for amusement simply, consisting of a collection of rare and grotesque objects, rose that which embraced the idea and purpose of education. With instruction, still variously larded with amusement, gradually came necessarily the last term of the series, viz., an eagerness for research. This last term, first put into ideal form by Lord Bacon in his "New Atlantis," near the end of the seventeenth century, in which he works the idea of a great national museum into his romance, was definitely recognized and enacted by parliament, in the establishment of the British Museum in 1753. The Louvre at Paris, containing the great national museum, was converted from a royal residence and playhouse when in 1789 it came into the possession of a republican government.

But I need scarcely mention, to this audience, those museums which exemplify the idea which I am trying to inculcate. If you call to mind those bee-hives of industry where are stored the choicest collections of years, or of centuries, representing all departments of knowledge, whether of natural science, or of history and antiquity, or of literature, or of art, in which the nations of the earth take the greatest pride, you see, perhaps, in Britain, the great British Museum, with its numerous departments and its libraries, or the United States National Museum at Washington, or some of the great continental museums. These great collections subserve the ends both of instruction and of research, but chiefly their purpose is to aid the student in research, although this was not the prime object in their establishment. As already

stated, however, when the second phase of museum-growth has been attained, viz., the idea of instruction, the last term of the series necessarily follows, and the museum takes on the last phase of its development — it becomes a place for research. It is by no means necessary that this last stage should exclude the functions of education and enlightenment. It is better that they co-exist. They aid each other. The instructed visitor may become an investigator, and the greater the number of enlightened visitors leaving its rooms, the greater the number of truth-seekers will be who frequent its laboratories and libraries.

As a museum takes on this highest function, however, it retires more and more from public gaze. Its cases and its drawers may be well filled with well-arranged and labelled specimens, and the casual visitor may imagine he has sufficiently seen the museum when he has passed through its public halls. But he has not seen the working of the museum in its highest departments. In the numerous laboratories are more specimens than those that are on exhibition. These are for the eye only of the true seeker after truth. The student-patron enters all the recesses, and has access to all the specimens. He alone invokes the muse in the spirit of the early Greek poet. Unobtrusively he solves his great problems. Unselfishly he proclaims the new truths to the world. His service is as sincere, and as necessary to the development of modern civilization, and to the apprehension of the laws of nature, whether they be the laws of gravitation or of brotherly kindness, as that of any truth-seeker or man-lover. The laboratories and recesses of these great museums, which are unseen by the public, are crowded with such devout truth-seekers.

We come now to consider in what manner this review can be made to apply to the people of Minnesota, and especially to the city of St. Paul.

On another occasion (Bulletin Minn. Acad. Sci., Vol. I., p. 389) I have attempted to set forth the superior advantages and inducements which Minnesota possesses for the cultivation of modern science. They need not be repeated here. I will simply refer to them. The lapse of eleven years since that time has served to confirm my statements, and to emphasize the reasons enumerated then for maintaining in the State a prosperous and active academy of science. I am still convinced that there will arise, either in St. Paul or in Minneapolis, an efficient scientific organization; and that its work, when duly established, will be of great benefit to the State along the line which is above indicated. It makes but little difference whether it be in St. Paul or in Minneapolis, nor under what auspices, or whether in both cities by a union of effort; its effect will be upon the whole State, and upon the North-west, and it will be the quickening and guiding power for the advancement of all practical and theoretical science, drawing about itself the enterprising and educated artisans of all classes, as well as the patient and studious investigators.

Such an institution would be a museum in the highest sense. I will try to sketch some of the prime essentials of such an institution, after the money is available for its establishment and support. It will not be necessary, were it possible, to state what amount of money should be placed at the back of such an institution, but I will permit you to estimate that as I proceed, and also to devise possible ways and means for raising it. To found anything, money must be had. Presuming, however, that the means for such a museum were at hand, I will simply outline a plan, and the equipment which should characterize it. We will assume that the institution will include within its scope only the natural sciences, so-called, although all sciences are natural.

The ideal museum should have, first, suitable permanent quarters for its local habitation. These quarters should be adapted to the uses to which they are to be put, and should be planned and erected with constant reference to economy of labor and time for the workmen who are to occupy it. This is so obviously necessary that it seems, at first, that it need not be stated. Yet its neglect is a common mistake. How often are the planning and construction of such a building put into the hands of some professional architect, with instructions simply to erect a building of good architectural proportions and fine appearance. In the main such a building should contain rooms for laboratories, for storage, for exhibition, classification, and, perhaps, for lectures.

Second, the ideal museum should have materials, in the form of multifarious collections, and the ways and means for increasing them, and of exchanging them with other museums. While some of these will be put on exhibition, at least those which have been sufficiently examined and classified, the larger portion will be kept in storage for the use of its collaborators.

Third, such a museum will be well supplied with apparatus and libraries, and the apparatus will consist of the best makes and of the latest improvements. I wish to emphasize the libraries. There is nothing that the scientific student so much needs and which he is most frequently without, as a library of those works which pertain to his science. He wishes to know what others have discovered, or what they have failed to discover, what methods others have followed, and what paths are still untrod. It is one of the difficulties of most scientific institutions, especially of new ones, to procure means for the scientific literature pertaining to the sciences which they are supposed to cultivate.

Fourth, for the efficient working of such a museum, there must be a corps of scientific collaborators, sufficiently paid to relieve them from anxiety for their comfortable subsistence, and that of their families.

Fifth, means for publication, either by lectures or by printing. It would be better that both these methods of publication be pursued. The former disseminates information quickly and cheaply. The latter is more formal, and more permanent, furnishing means for recording facts and principles with carefulness and thoroughness, and with a view to future reference.

Sixth, such a museum should have its administration unified and harmonized by being under the responsible charge of one man. There should be a plan for its work, outlined by the proper authority, and that plan, with the rules which it should involve for the government of all the collaborators, should be enforced with persistence and fidelity.

Are we ready for such a museum in the State of Minnesota, or for such an institution under any other name? Are the citizens of St. Paul ready to undertake such an enterprise? Have we the elements which enter into such an organization at our command, or any part of them? Have we the live nucleus round which such an institution can be built up? Have we the men who will devote themselves to its establishment and support?

I have seen something which Ex-Governor McGill has said recently on this subject, and it is so apropos that I will repeat it here: "There should be somewhere in Minnesota a great polytechnic school which would impart instruction in mineralogy, mechanics, and the various arts and sciences usually taught in such institutions. This should be established on a large, comprehensive scale, making it a university in its scope. Such an institution would attract the attention of all the country, be a lasting benefit to the city of its home, and meet a pressing public demand for industrial and technical education. St. Paul is the place for such a school, provided always she has the intelligent enterprise to establish it." These are the words of one of our ex-governors, whose means for knowing the needs and the facilities for higher scientific education in the State may be supposed to be the best.

There are numerous museums, and schools of technology, and so-called mining schools in the United States, which in a measure subserve the purposes which I have set forth for an ideal museum. The American Museum of Natural History in New York, the Museum of Comparative Zoology at Cambridge, the New York State Museum at Albany, the Philadelphia Academy of Sciences at Philadelphia, the School of Technology at Boston, supplemented by the museums and libraries that are adjacent, these are based essentially on the central idea of a true museum, such as we ought to have in Minnesota. Similar plans underlie the scientific work at several of the larger universities, but in these institutions the fogs of mediæval prejudice are apt to dwarf the growth of scientific work, and to overburden the few and struggling preceptors with the elementary instruction which ought to be required of the student before he enters the freshman class.

If we take an inventory of the elements which we have toward such an institution in St. Paul, we shall find the following: First of all, the St. Paul Academy of Sciences, which is apparently willing to serve the public in the cause of scientific enlightenment.

This may be considered the germ, which, by its growth, may quicken with its spirit all the other elements. Second, the Minnesota Historical Society, whose plan of organization, however far it has lapsed from it, is so broad that it embraces the objects which we seek, and which would be a powerful factor in any re organization for scientific work in St. Paul. Its library, its collections, and its good will would go far toward causing the State legislatures to vote enlarged funds for its sustenance, should the ideal museum be made to include this society. Third, the Public Library of St. Paul should be mentioned as one of the elements at hand which should be brought within the pale of this ideal museum. There may be other libraries and organizations of which I am not cognizant, whose usefulness and whose expressed aims would be better subserved by a combination with others.

Add to these elements an enlightened and wealthy community, largely in sympathy with the advanced science of the day, and, I think, we have mentioned every thing on which we can depend. There are, however, other nearly allied institutions which might be willing to co-operate, and, on the plan of "university extension," join in whole or in part in a general movement. I refer to Macalester College and Hamline University. Should all these elements express a willingness to join in the creation of a great central scientific institution, for which I would retain the name of "Museum," they should all be housed in one building or series of buildings, and should be brought under one administration. Their efforts would then be brought into sympathetic and harmonious activity, and instead of smothered jealousy, one of the other, each one would have its function so defined that they would help rather than hinder each other, and the result would be a conservation of energy and money, which now are sometimes lost by being duplicated from different sources, or by being ill-advised and ill-directed.

I have sketched out what appears to me to be the museum of the future in Minnesota. I have indicated what should be its plan and its purpose. I have shown the necessity existing for such a scientific centre in this State, and I have lastly enumerated the elements that might be united in such an institution in St. Paul. The immediate steps that should be taken to bring about such an end, it will be necessary for you to decide upon should it be attempted. For nineteen years I have had the hope that such a museum might arise in Minnesota, and that in my day I might be in a measure instrumental in bringing it about. I would like to inspire some of the wealthy friends of science who reside in St. Paul with the faith which started some of the great museums of the world, or with the consecration which actuated Agassiz, or Smithson, or Rensselaer, or Franklin, in founding the institutions which bear their names.

NOTES AND NEWS.

THE effect of adding aluminum to steel ingots was discussed at considerable length at the recent meeting of the American Institute of Mining Engineers, communications on the subject by Professor J. W. Langley of Pittsburgh and Professor J. O. Arnold of Sheffield being among the papers read. Professor Langley drew attention to the very small quantity of aluminum required to render steel castings perfectly sound. The aluminum, says *Engineering*, is added in small pieces of from a quarter to a half pound in weight, thrown into the ladle during the tapping after a small quantity of steel is already in it. The aluminum melts almost instantaneously, and diffuses with great rapidity throughout the contents of the ladle. For open-hearth steel, containing less than .05 per cent of carbon, five to ten ounces of aluminum are sufficient for each ton of steel, while for Bessemer steel the amount should be increased to from seven to sixteen ounces per ton. For steel containing more than .5 per cent of carbon the aluminum should be used cautiously in amounts of from four to eight ounces per ton. Professor Arnold described briefly the results of a number of experiments at the Sheffield Technical School, from which he concludes that the action of aluminum is about twenty times as powerful as that of silicon, and the resulting steel is tougher and sounder than when silicon is used, provided that certain precautions against piping are taken. He considers that the action of the aluminum is almost certainly chemical. The blowholes in ingots are due to occluded gases, and it has been proved by experiment that aluminum readily reduces carbonic oxide at a temperature below that of melting steel. In one experiment Professor Arnold blew forty gallons of pure carbonic oxide through a crucible of molten steel containing aluminum, with the result that the carbon in the steel was increased by thirty-five per cent, owing to the reduction of the gas. He concludes that by using aluminum, manganese can be dispensed with, and a considerable saving of time and fuel effected.

— A new antiseptic, said to have certain advantages over those hitherto in use, has been brought before the French Academy of Medicine by Professor Berlioz of Grenoble. Extreme solubility, harmlessness, efficacy, and rapidity of action are claimed for it. It is called "microcidine," and, as described by *Nature*, is a compound of naphthol and soda, is neither poisonous nor irritant, is twenty times as active as boric acid, and much more soluble than thymol, carbolic acid, etc. Microcidine has the form of a grayish white powder. In a solution of three grams per litre it is very slightly colored, but it does not stain either the hands or bandages. For family use it is said to be of great service.

— An apparatus has been recently constructed by M. Ducretet, says *Nature*, for getting quickly in the laboratory a fall of temperature 70° to 80° C. below zero, by means of the expansion of liquid carbonic acid. The inner of two concentric vessels contains, in alcohol, a serpentine metal tube communicating, through a tube with two stopcocks, with the carbonic acid reservoir outside, and opening below into the annular space round the inner vessel, in which are some pieces of sponge impregnated with alcohol. This two-walled vessel with coil is inclosed in a box. One stopcock being opened wide, the other slightly, the carbonic acid passes through the coil as snow, and turns to gas, with strong cooling effect, and any of it not vaporized in the coil is dissolved in the alcohol of the sponge. The gas escapes through a tube passing through the outer box. The instrument, called a *cryogen*, is pictured in *Cosmos* of June 27.

— Experiments have lately been made by Herr Regel (*Bot. Centralb.*) with reference to the influence of external factors on the smell of plants. In the front rank, as stated in *Nature*, appears the direct and indirect influence of light on the formation of etheric oils and their evaporation. In the case of strongly fragrant flowers (as *Reseda*), heat and light intensify the fragrance, which in darkness is lessened without quite disappearing. When the whole plant was darkened, those buds only which were before pretty well developed yielded fragrant flowers; the others were scentless. If, however, only the flowers were darkened, all were fragrant. Other plants open their flowers and smell only by night (as *Nicotiana longiflora* and *Nycterinia copensis*). When these plants were kept continuously in the dark, they, in course of time, lost their scent, as they lost their starch. On being brought into light again, both starch and fragrance returned. Besides light, respiration has a decided influence on the fragrance. Nycterinia, inclosed in a bell jar with oxygen, behaved normally, but with hydrogen the flowers did not open, and had no fragrance. In general, the opening of flowers coincides with their fragrance, but there is no necessary connection between these phenomena.

— Dr. Anderson, in a recent paper on steel read before the Iron Institute, London, explains the peculiar action of the solid iron when thrown into molten metal. When thrown into a pot of molten iron or steel the solid metal at first sinks, which shows that its volume per unit of weight is less than the heated metal. But soon the solid piece becomes heated, which causes it to expand, its volume is increased, and it rises and floats on the surface of the molten mass. The action is the same with both iron and steel. The experiment was frequently made by throwing a piece of iron into melted steel. It could be seen to go down, and one might think it was on account of the impetus which the iron had attained in falling that height, but as a matter of fact if the iron were put upon a fork and lowered, it would go down. In the course of a few seconds it came up again, and kept on expanding until the piece of iron was a considerable distance above the surface of the metal. Then it decreased in volume, and of course

became of the same volume as the molten metal which it joined. Any one could see by the distance that the piece of iron went above the surface that it was of considerably less density than the molten metal.

— The German East Africa Company, according to press reports, has decided to spend $15,000,000 in building a railroad from Tanga to Karagwe. Tanga is a little seaport about fifty miles north-west of Zanzibar, and Karagwe is distant from the starting point about 625 miles. It is the country of the good old King Rumanika, who so charmed both Speke and Stanley that they credited him with most of the virtues, and pictured his country as an African paradise. The proposed railroad, by starting from Tanga, will avoid the hard climb up the Usagara Mountains. It will doubtless run almost due west to Tabora, the centre of things in inner East Africa, and will then strike north and north-west to Victoria Nyanza and Karagwe, which is within a hundred miles of the western boundary of Germany's possessions.

— The manuscript of the annual report of the Ohio experiment station was placed in the hands of the State printers in January, but the press of other work has crowded it back, so that it is only now being printed. The report contains a summary of the year's experiments, the full reports of which have been published in bulletins issued during the year. Among the subjects under investigation have been: potatoes, including trials of varieties, use of fertilizers, size of seed; commercial fertilizers, including trials on corn, wheat, and oats at the station and on farms in various sections of the State; experiments with corn, oats, and wheat, including tests of varieties, quality of seed, date of planting, and methods of culture; experiments in the control of insects affecting fruits, vegetables, and field crops; experiments in the control of fungus diseases of plants, as smuts, rusts, mildews, fruit rots, etc.; experiments with many varieties of fruits and vegetables, and investigations in some of the diseases of animals. The publications of the station for the year are, its regular bulletin, of about 260 pages; the annual report, some 60 pages; and a technical bulletin, of 100 pages, intended primarily for the use of other scientific workers. All are illustrated, and all are distributed free of cost to all persons in Ohio who are interested in agriculture or horticulture. Applications should be addressed to Experiment Station, Columbus, O.

— In the journal of the Elisha Mitchell Society, Mr. Atkinson calls attention to two new cases of protective mimicry in spiders. A *Cyrtarachne* takes shelter in summer and autumn under leaves, where it has absolutely the aspect of a small univalve mollusc, which is extremely abundant, and which often fixes itself in an analogous position. The second example is found in a small spider, *Thomisus aleatorius*, which is remarkable for the length of its fore-legs, the hind ones being, on the contrary, very short. This spider, which lives upon grasses, ascends the culm, stops suddenly, and disappears from sight. It suffices to fasten itself to a spike by its hind-legs, and to bring together its fore-legs, extended, and form an angle with the culm in such a way as to make itself nearly undistinguishable from the spikelets.

— Ultramarine has long been a chemical puzzle, alike in its constitution, the cause of its color, and the vicissitudes of its manufacture, but now, says *Industries*, there is reason to suppose that one of these questions is in a fair way to be definitely solved. Some time ago it was suggested that the color of ultramarine was due to the presence of an allotropic modification of the element sulphur, a substance capable of many vagaries. Mr. F. Krapp has recently pursued the former line of inquiry by investigating the so-called "black sulphur" of Magnus, which he finds to be not sulphur only, but a mixture of a certain modification of sulphur with a compound containing both sulphur and carbon. This modified form of sulphur by mere subdivision gives a blue color to the substance used to subdivide it, and there appears to be little doubt that ultramarine simply consists of a basis of colorless silicates impregnated with blue sulphur, resulting from the sodium sulphide formed in the ordinary course of manufacture. As blue sulphur in a state of isolation is unstable, and quickly passes into the yellow variety, it is easy to understand that on decomposing the colorless base by means of an acid, the sulphur itself undergoes change, and ultramarine as a pigment ceases to exist. Mr. Krapp suggests that this same modified form of sulphur may play a part in the production of vulcanite, and that the blue color of certain blast-furnace slags may be due to it. In any case, sulphur which boils at a temperature far above 440 C., whose vapor is colorless, which oxidizes to sulphur dioxide without visible combustion, and which itself is moreover blue, is a body sufficiently remarkable to warrant further research.

— It is more than probable, says *Iron*, that the Egyptains were in the habit of transporting vessels overland across the Isthmus of Suez, and tradition records that twenty-three centuries ago a true ship-railway, with polished granite blocks as rails, existed and was worked across the Isthmus of Corinth, where the construction of a ship-canal has been projected. In 1718 the well-known Count Emanuel Swedenborg constructed a road and "machines" for carrying laden vessels from Stromstadt to Iddefjord, in Sweden, a distance of fourteen miles across a rough country, and the successful use of this work by Charles XII. during the siege of Frederikshall led to Swedenborg being regarded not only as a national benefactor, but as a mechanician of no mean ability, for at least a century after his death.

— The census of British India was taken on Feb. 26 by nearly a million enumerators. According to the London *Times*, the population was found to be nearly 286,000,000, of whom 220,500,000 live in British territory, and 65,500,000 under feudatory governments. The increase during the past decade has been 26,000,000, or 29,000,000 if newly acquired districts be included. The density of population is 474 to a square mile in Bengal, 442 in the North-western Provinces, and 248 in Madras. In Sind the growth of population has been very marked. Burmah has also made rapid progress, owing to the abundance of land ready for new settlers, and Lower Burmah is now as densely peopled as Portugal. As regards the towns, Calcutta now stands first and Bombay second, but changes in town areas and errors in the preliminary report render it impossible to give an accurate comparison of urban populations at present.

— An interesting report, by Mr. Campbell, of the British Consular Service in China, has been issued by the British Foreign Office. According to *Nature*, it is the record of a journey of over 1,300 miles in districts in northern Corea, many of which have never before been visited by Europeans. Mr. Campbell started from Seoul, the capital, and crossed the peninsula to the treaty port of Won-san (Gensan), and thence pursued his way along the east coast around Broughton Bay, whence he turned north-eastward, crossing the Yalu River to Päik-tu-San, known to Europeans as the Long White Mountain, and already visited by Messrs. James, Fulford, and Younghusband. The return journey was partly over the same ground, but on arriving at Won-san Mr. Campbell recrossed the peninsula, and so made his way to Seoul. Besides the ordinary record of this journey Mr. Campbell gives a great amount of information on various subjects connected with Corea. The chief amongst these is a most interesting section on the prevalence of Buddhism in the peninsula, and one on the agriculture and productions. He gives a good deal of information in regard to the geography of northern Corea, and also of the gold production of the country. That Corea contains gold-bearing strata has long been known through the export of gold-dust from the ports, but from Mr. Campbell's report it appears that gold-fields do exist in considerable numbers, and that some of them are worked with the imperfect native methods. There seems no doubt that, if circumstances were favorable to the proper scientific working of the Corean gold-fields, the country would be one of the principal producers of the precious metal in the world. Education in the country seems to be at a very low ebb, and is confined to a knowledge of Chinese. All energy and enterprise is crushed out by an all-pervading tyrannical officialism, and poverty and squalor are universal.

— O. C. Charlton, late of Ottawa, Kan., has been appointed professor of natural sciences in the Texas Normal College at Denton.

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INVESTIGATIONS UPON NITRIFICATION AND THE NITRIFYING ORGANISM.[1]

THE nitrogen of organic substances is, for the most part, liberated during decay in the form of ammonia or ammoniacal compounds; and these substances yield, by oxidation, nitrous acid and finally nitric acid, which, in turn, in the form of nitrates, feeds the living plant, and thus begins again the cycle of transformation.

The oxidation of the nitrogen of ammonia, and its ultimate conversion into nitric acid, is called nitrification. This change is especially active in soils near the surface, where nitrates are formed abundantly from percolating waters which contain much nitrogenous matter.

This phase of nitrification, the formation of nitrates in porous soil, has been attentively studied: but less attention has been given to the process of nitrification as it goes on in surface waters, such as streams and ponds; and it is to this side of the question, namely, nitrification as it occurs in natural waters, that our study has been chiefly directed.

Some eighty samples of water, selected from the two hundred and forty coming each month to the laboratory of the State Board of Health, were examined at intervals of from two to seven days for ammonia, nitrites, and nitrates. These samples were received from all parts of the State, and included all classes of surface water, rivers, ponds, and reservoirs. They were examined repeatedly during the months of June, July, and August, 1888.

The results may be briefly stated as follows. The organic matter in suspension decays in about seven days, as is shown by the increase in "free ammonia." In about fourteen days this "free ammonia" has disappeared, and nitrite has taken its place, reaching a maximum in about twenty-one days. Later the nitrite too disappears, and in twenty-eight days or more all the nitrogen has been converted into the form of nitrate. When the suspended matter is removed by filtration through paper, or by precipitation with alumina, no change occurs unless free ammonia were present at the outset.

These changes were so universal, and so independent of the character of the water and of its condition of aeration, that it seemed important to avail ourselves of the unusual opportunity offered by the close proximity of the chemical and biological laboratories of the State Board of Health, to carry on a series of chemical and bacteriological investigations on solutions of known composition. Accordingly, we began a series of experiments covering a period of nearly two years, in which the daily and weekly changes caused by the growth of bacteria were watched from both the chemical and the bacteriological standpoint, in order to determine the sequence and rate of such changes. Other points came up in the course of the work, as will appear from the following pages.

It has long been known that the first step — the decomposition of nitrogenous matter, and consequent production of ammonia — is due to the vital activity of bacteria. The early experiments of Schwann and Schultze (1839), and the later and thoroughly conclusive work of Pasteur, showed that putrefaction of organic matter is brought about solely by the small vegetable organisms known as bacteria. Even after this fact became generally known, it was some time before the importance of the complete range of this discovery was suspected. It was still maintained that the process of nitrification proper — the oxidation of ammonia to nitric acid — was of a purely chemical nature, although the burden of proof was soon thrown on those who upheld this view. The close dependence of nitrification upon a rather narrow range of temperature, the cessation of the process on the addition of antiseptics, the operation of "seeding" one solution with another, the impossibility of effecting rapid nitrification by chemicals, the analogous phenomena of putrefaction, — all pointed clearly to the fact that nitrification depends on the presence of living organisms.

The first conclusive proof that such was the case, however, came from the work of Schlœsing and Muntz in 1877 (Comptes Rendus, 1877, Tome 84, p. 301). The work of these observers rendered it practically certain that living organisms of some kind are the true agents of nitrification. "It now remains for us," they said, "to discover and isolate the nitrifying organisms." Schlœsing and Muntz, in their subsequent investigations, believed that they had succeeded in making this discovery; but, in view of the facts of modern bacteriology, we are unfortunately unable to assign much value to this part of their work. It is not easy to satisfy one's self that Schlœsing and Muntz ever worked with really "pure cultures" of isolated species. While the work of these investigators established beyond all question the fact that nitrification, like the analogous phenomena of fermentation and putrefaction, is caused by living organisms, it left entirely open the precise nature of these organisms.

The first experiments with species of bacteria isolated by modern methods, and therefore undoubtedly pure cultivations, are those recorded by Heræus (Zeitschr. für Hygiene, I., 1886, p. 193). Heræus experimented with fourteen well-known species of bacteria, and with about as many others freshly isolated by himself from water and soil. He cultivated these in an ammoniacal solution, and obtained in the case of several familiar species good qualitative tests for nitrous acid. Among these species were *Bacillus prodigiosus*,

[1] Edwin O. Jordan and Ellen H. Richards, in report on water supply and sewerage to the State Board of Health of Massachusetts. (The series of experiments detailed in this paper were planned and carried out jointly by the authors, the bacteriological portion of the work being done by Mr. Jordan, and the chemical portion by Mrs. Richards.)

the Finkler-Prior bacillus, the bacillus of typhoid-fever, the anthrax bacillus, and others. Heræus concludes that all these organisms possess oxidizing powers, since they are thus apparently able to oxidize ammonia to nitrous acid.

The work of Adametz (Untersuchungen über die niederen Pilze der Ackerkrume. Inaug. Diss., Leipzig, 1886) and Frank (Forschungen auf dem Gebiete der Agriculturphysik. X, 56), on the other hand, did much to offset this positive result reached by Heræus. They found, as other investigators had found before them, that the introduction of a small quantity of garden soil into an ammoniacal solution would produce rapid nitrification. The various species of bacteria, however, which they isolated from this same soil, and introduced as pure cultures into sterilized ammoniacal solutions, refused to nitrify. In no case was more than a trace of nitric acid observed. Frank was so influenced by his continued negative results that at a later date he went so far as to deny that living organisms had anything whatever to do with nitrification. This sceptical attitude seemed for a time to be fully justified by the experiments of Celli and Zucco. It was soon, however, demonstrated by several skilful investigators that nitrification could not be accounted for by purely chemical influences. There was, nevertheless, no cessation in the publication of negative results. The work of Heræus was extended and elaborated by P. F. Frankland and by Warington. Frankland (Jour. Chem. Soc., April, 1888, Vol. LIII., No. CCCV., p. 373) failed entirely to obtain any evidence of oxidation of nitrogen by individual species of bacteria, and on this point came into direct conflict with Heræus. To use his own words: —

"The [ammoniacal] solutions were examined after forty days' growth, but in no case was anything more than a faint indication of nitrous acid obtainable with sulphanilic acid, phenol, and ammonia.

"It is worthy of notice that Heræus had experimented with three of the micro-organisms which we have had under observation, viz., *B. subtilis*, *B. prodigiosus*, and *B. ramosus*. On growing these in sterilized urine, he found that *B. subtilis* alone gave no nitrous acid reaction, whilst the other two gave distinct reactions for nitrites; from this he concludes that *B. prodigiosus* and *B. ramosus* possess oxidizing powers, and that *B. subtilis* does not. My experiments, however, conclusively prove that both *B. ramosus* and *B. prodigiosus* exert a reducing action, whilst *B. subtilis* does not; and therefore that the nitrous acid reactions which he obtained in the case of the two former organisms must obviously have been due to the reduction of the nitrate in the urine, and not to oxidation of ammoniacal nitrogen, as he supposes. That nitric nitrogen is an invariable constituent of human urine has been shown by Warington (Trans. Chem. Soc., 1884, p. 669), and has in fact been long known." Frankland summarizes his results as follows: "8. None of the organisms under examination were found capable of oxidizing ammoniacal nitrogen to nitrous or nitric acids, when introduced into a nutritive solution containing ammonium chloride."

This emphatically negative result with pure cultures of single species was directly confirmed by Warington, who wrote: "It seems to me very clear that not one of the investigators who have experimented with isolated species of bacteria has obtained in his solutions more than a trace of nitrous or nitric acid; no one has obtained an amount that could be determined quantitatively. Another point which generally appears is that every organism tried gives nearly the same result. . . . The statement of Heræus that seven of the organisms examined commenced the nitrification of a twenty per cent urine solution in one day is apparently due to a mistake. My own experiments show that a urine solution of that strength cannot be nitrified by soil without the addition of gypsum; the commencement of nitrification in a strong solution is also extremely slow. The nitrous acid which so speedily appeared in his solutions was due to the reduction by the organs of the nitrates naturally present in the urine" (Journ. Chem. Soc., August, 1888, Vol. LIII., p. 727). Of his own experiments, he says: "A distinct reaction with diphenylamine was in some cases obtained, but this did not appear to grow in amount, although in such cases the examination was specially prolonged. The amount of nitric or nitrous nitrogen in the solutions did not apparently in any case exceed one per million, and all of this could not be attributed to the action of the organism, as the unseeded solutions in the incubator also gave some reaction with diphenylamine. When we have discounted the trace of nitrites probably obtained from the atmosphere, there is clearly very little left that can be attributed to the action of the organism. The question whether any part of the nitrate or nitrite present was produced by the organism, I am unable to decide; but it is quite clear that none of the organisms examined possessed any nitrifying power in any way comparable with that possessed by soil. An organism which nitrifies as soil nitrifies has yet to be isolated."

There are thus several views which are held regarding the action of individual species of bacteria on nitrogenous solutions: —

1. That there is a group of bacteria capable of oxidizing ammonia to nitric acid, and another and separate group able to reduce nitrates to nitrites in the presence of organic matter. Both kinds are widely and abundantly distributed. Attendant circumstances determine whether the reducing or the oxidizing group will gain the upper hand (Heræus).

2. That all kinds of bacteria, under favorable circumstances, are capable of producing nitric acid, and that the same organisms in the presence of organic matter are capable of reducing nitrates (Celli and Zucco, Leone).

3. (*a*) That different species of bacteria vary greatly in their ability to reduce nitrates; and (*b*) that there is no reliable evidence that any individual species is able to oxidize ammonia either to nitric or nitrous acid (Warington, Frankland).

Such is a brief sketch of the divergent opinions upon nitrification which were held at the time we began our work in the autumn of 1888. It seemed to us important to approach the subject from all sides, and we have worked accordingly not only with pure cultivations of bacteria, but also with various sands, soils, and waters containing mixtures of several kinds. We have considered it of fundamental importance to determine the distribution of the nitrifying organism, and, if possible, to ascertain the relative frequency with which it occurs over a wide area. The question, for instance, naturally arose, is the nitrifying organism present in the Boston city water as delivered from the tap in the laboratories of the Massachusetts Institute of Technology, since this is the water used in making up our solutions. To this question we are able to give a decided affirmative. Ammoniacal solutions carefully made with tap water always nitrify. Moreover, ammoniacal solutions which have been sterilized and then inoculated with a cubic centimetre of fresh tap water always nitrify. Repeated experiments show that the nitrifying organism is invariably present in this water. When, however, ammoniacal solutions were inocu-

lated from the separate colonies appearing on a gelatine plate culture of this water, in every instance there has been obtained only a negative result. To this matter of inoculation with pure cultures of bacteria we shall recur presently.

In many of our early experiments upon nitrification we used a mixture of one cubic centimetre of fresh urine with two litres of tap water. This mixture was found to yield, when freshly made, about .5000 free ammonia, .2000 albuminoid ammonia, .0002 nitrites, and .0250 nitrates, in 100,000. This nitrogenous solution was allowed to stand at the temperature of the room (21°–23° C.), and was tested from time to time for nitrites and nitrates. The method used for the determination of nitrites has been Griess's naphthalamine method. This method is sufficiently delicate to detect the presence of one part of nitrogen as nitrite in one thousand millions. The method for determining nitrites is a modified form of the phenolsulphonic method of Grandval and Lejoux.

If the nitrogenous solution be first sterilized and then inoculated with fresh tap water, the same course is followed, with the exception that the period of incubation is considerably lengthened. If seeded with sand from a sewage filter tank, or with garden soil, the whole process is materially quickened, and may even be wholly completed in thirty days.

Not only is the nitrifying organism present in Boston tap water, as the above experiments clearly demonstrate, but it appears to be equally common in water from all parts of the State of Massachusetts. So far as our experience has gone, any natural water, containing the ordinary amount of free or albuminoid ammonia, contains also the nitrifying organism, as is shown by our long series of tests. In these natural waters the nitrifying organism seems to be under wholly normal conditions, and to be abundantly able to effect the oxidation of the small quantities of nitrogen usually present in these waters. Waters that contain high albuminoid ammonia, in cases where this ammonia comes from the nitrogen in infusoria, algæ, etc., go through the same changes as those which contain free ammonia, but more slowly. The organisms in time die, the bacteria set free the nitrogen of their bodies, forming free ammonia, and then in turn nitrites and nitrates.

It might, perhaps, be reasonably expected that, since the nitrifying organism is undoubtedly present in all these waters, an examination of gelatine plate cultures of these waters would reveal some particular kind or kinds of colonies common to all, and in that way aid in sifting out the nitrifying organisms. Our experience has shown, however, that such a hope is unfounded. So far as the inspection of gelatine plate cultures enables us to judge, no one kind of colony is common to all these waters. This fact, on the surface, seemed to favor the view that the power of nitrification was not the property of any particular organism, but was very likely possessed in common by a number of kindred species.

The other line of bacteriological work — the inoculation of nitrogenous solutions with pure cultures of isolated bacteria — has been followed up from the outset, and was begun with full confidence in ultimate success. It is unnecessary to give a detailed account of our experiments in this direction. It is sufficient to say that the nitrogenous solutions have, from beginning to end, failed to nitrify. Nitrogenous solutions of various sorts have been used, pepsin solutions, peptone solutions, ammonium chloride solutions, Frankland's solution (Zeitschr. für Hygiene, Bd. VI., 376), etc., all with the same unfailingly negative result. A large number of species of bacteria have been used for inoculation, not only well-known species like *B. prodigiosus*, *B. megaterium*, *Proteus*, etc., but many species freshly isolated from water, sewage, the sand of nitrifying filter tanks, and similar favorable situations for the nitrifying organism. The experiments have been always prolonged for several months, and in some cases for more than a year. Conditions of temperature, amount of surface exposed to the air, etc., have been varied in many directions. Nitrogenous solutions containing a single species of bacterium have been poured upon sterilized sand, and allowed to settle in such a way as to imitate closely the conditions obtaining in filter tanks. In all, more than one hundred and fifty experiments have been made, covering a period of two years. In every case, without a single exception, there was not the slightest evidence of nitrification by any single species.

There still remains a plausible explanation of this striking succession of negative results. It might be that, although any one species working alone was not able to effect nitrification, a number of different species working together might be able to produce the desired result. This was certainly not an unreasonable supposition, judging from analogous fermentative processes; co-operation and combination might perhaps effect more than individual and independent action. Several experiments were accordingly made with a view of determining this point. Here again the results were invariably negative. Ammoniacal solutions, inoculated with mixtures of several species under pure cultivation, always failed to nitrify. In one experiment, for example, a nitrogenous solution, found by experience to nitrify rapidly and completely when seeded with garden soil, was inoculated with a mixture of six different species of bacteria. These six species were all isolated from soils and waters known to contain the nitrifying organism. An examination of the solution from time to time, by the method of gelatine plate culture, showed a vigorous growth on the part of all the species, but there was at no time the slightest evidence of nitrification, although the experiment continued for upwards of five months.

In the course of our experiments we have found it necessary to guard against two possible sources of error. We noticed at the outset a tendency in all our solutions, whether inoculated with pure cultures, or entirely free from bacteria, to show an increasing quantity of nitrogen as nitrite. This increase of nitrite in standing solutions is shown in the following instance. A nitrogenous solution, placed in a flask stopped with cotton wool, was sterilized in the usual way, and allowed to stand in the laboratory. At first no nitrogen in the form of nitrite was present, but after one month .003 parts per 100,000 had appeared, and at the end of three months .008 parts of nitrite were present. In some cases a much larger amount than this appeared, although no bacteria were in the flasks. In all these instances nitrite was undoubtedly absorbed from the air of the laboratory. Sterilized distilled water was found to absorb nitrite with the same rapidity as did our nitrogenous solutions, in one case absorbing .0015 in a few days. If the solutions were protected from the free access of air, no increase of nitrite was noted, and there was also no increase if they were removed to a room in which little or no gas was burned. In rooms in which much gas is burned it is obvious that, with the present refined methods for detecting nitrites, this absorption from the air, unless guarded against, may lead to erroneous conclusions. This fact of nitrite absorption from the air has been already noticed by Warington and other observers.

A second possibility of misinterpretation lies in the reduction of the nitrates that may be present in the solution. This reduction takes place even when the quantity of nitrate and organic nitrogen is small, although more slowly than is the case in the presence of considerable quantities of organic nitrogen. In one example there were no nitrites and .036 nitrates present at the beginning of the experiment in the sterilized solution. On inoculation with a certain bacterial species, afterward found to possess a reducing action, the quantity of nitrogen as nitrite increased in a short time to .0256, while the nitrate diminished to .015. On another occasion, with .036 initial nitrate, the nitrites rose from nothing to .021, and the nitrates disappeared proportionally. If larger amounts of nitrate are present, the increase of nitrite is more striking. Certainly this reducing action of many species of bacteria will go far to explain such results as those reached by Heræus (*loc. cit.*).

An interesting experience, and one very significant in the light of our further investigations, should here be mentioned. A nitrogenous solution prepared in the usual way was inoculated with a certain species, — *Bacillus ubiquitus*, — and examined from time to time, both chemically and bacterially. The solution, on standing for several months, nitrified completely, and the gelatine plate culture showed the presence of a pure culture of *B. ubiquitus*. We naturally concluded that we had discovered a nitrifying organism; but repeated inoculations with a culture of this same organism, both from the flask that had nitrified and from the original growth in a test-tube, gave a negative result. No better success was had with the same organism freshly isolated from water or soil. No explanation of this perplexing occurrence could be given at the time, but subsequent events made it probable that our assumed pure culture was not a pure culture at all, but a mixture of the nitrifying organism and *B. ubiquitus*. Whether the nitrifying organism was introduced from the air, or, as seems more likely, accompanied the first inoculation with *B. ubiquitus*, is unknown. Possibly some of the investigators who have claimed a positive result with species of bacteria grown on gelatine may have been misled in a similar way.

There was, as has been intimated, one possible explanation of our failure to reach consistent positive results by the use of species of bacteria isolated by the method of gelatine plate culture. It might be that the nitrifying organism did not grow on gelatine. Everything seemed to point in this direction, and the belief was further strengthened by a very significant fact observed about this time. We had known for some time that in the history of the filter tanks at the Lawrence experiment station speedy nitrification was always coincident with a marked decline in the numbers of bacteria. The effluents discharged from the filter tanks, although high in nitrates, were low in bacteria; and, moreover, the more complete the nitrification, the fewer were the bacteria in the effluent.

We also observed, that, in an ammoniacal solution which is seeded with ordinary pond water containing several species of bacteria, there is during the first few days a rapid multiplication of the contained germs. Nitrification, however, does not as a rule begin until from ten to fourteen days have elapsed. By the time nitrification begins, the numbers of bacteria, as shown by gelatine plate cultures, have begun to decline; and, while the nitrogen in the form of nitrites in the solution is increasing, the numbers of bacteria are steadily diminishing. Thus, in one instance, an ammoniacal solution, four days after its inoculation with a cubic centimetre of Cochituate water, contained 3,762,000 bacteria per cubic centimetre. Nitrification had not yet begun. When the first signs of increasing nitrites appeared, the numbers of bacteria had sunk to 19,200; and when the nitrites reached their maximum, the bacteria, shown by gelatine plate cultures, were only 9,454. It was certainly difficult to understand why nitrification, a process apparently dependent upon the life and activity of bacteria, should seem to flourish best under conditions in which bacteria were perishing. If, however, it were assumed that the nitrifying organism could not grow in the usual gelatine media, all the perplexing results above recorded could be more easily explained. Under these circumstances it was natural for us to make such an assumption.

There was, of course, the possibility that the nitrifying organism, by its growth on gelatine, had lost its peculiar property; but it did not seem to us likely that so fundamental a property could be parted with in so short a time. However that might be, we determined to test the other hypothesis first, since we believed it to be the more probable of the two. Accordingly, experiments were begun to attempt to isolate the nitrifying organism by the method of dilution. This is the method that was commonly used by investigators in bacteriology before the invention of solid culture media. It has, as is well known, serious practical as well as theoretical drawbacks. In our practice a small portion of an actively nitrifying solution is transferred on the loop of a sterilized platinum needle to a sterilized ammoniacal solution, and when nitrification is thus induced in the second solution a fresh transfer is made from this to a third, and so on. Rigid precautions have been taken to avoid the introduction of foreign germs.

Hardly were these experiments well under way, before our interest in this method of procedure was stimulated by the publication of communications by Percy F. Frankland and Grace Frankland, and by Robert Warington (Chemical News, Vol. LXI., p. 135).

The Franklands, having reached a conclusion similar to our own regarding the behavior of the nitrifying organism in gelatine, had also attempted to isolate the nitrifying organism by the dilution method, and had succeeded in this attempt. They state, in their abstract of the paper read before the Royal Society, that, "after a very large number of experiments had been made in this direction, the authors at length succeeded in obtaining an attenuation consisting of about $\frac{1}{1000000}$ of the original nitrifying solution employed, which not only nitrified, but, on inoculation into gelatine-peptone, refused to grow, and was seen under the microscope to consist of numerous characteristic bacilli, hardly longer than broad, which may be described as bacillo-cocci."

Warington's communication entirely confirms that of the Franklands, in so far as it relates to their earlier and negative results. He had not, however, at the time of writing, succeeded in isolating the nitrifying organism.

A paper by Winogradsky followed soon after. He appears to have discovered independently a nitrifying organism, and attributes his success largely to his microscopic examinations of the nitrifying solutions, and to his use of solutions devoid of organic matter. The following is the composition of the liquid adopted by him: ammonium sulphate, 1 gram; potassium phosphate, 1 gram; water from the lake (at Zurich) 1,000 grams. Each portion of 100 cubic centimetres received in addition .5 to 1 gram of basic magnesium carbonate, suspended in distilled water. Winogradsky found that this layer of magnesium carbonate at the bottom of each flask

afforded an excellent gathering place for flocks of the nitrifying organism. The "nitric ferment" does not, as the Franklands had already shown, grow well upon ordinary gelatine plate cultures; and this is probably the cause of the failure of all previous experimenters to isolate the special ferment.

Before receiving Winogradsky's paper, in the spring of 1890, we had been using in our work, at the suggestion of Mr. Allen Hazen, an ammoniacal solution of the following composition: ammonium chloride (resublimed), 1.907 grams; sodium carbonate, 3.7842 grams; sodium phosphate, .2 grams; potassium sulphate, .2 grams. These salts were dissolved in such a quantity of re-distilled water that the solution contained 100 parts of nitrogen per 100,000, and two equivalents of alkali. Ten cubic centimetres of this solution were mixed with one litre of re-distilled water, and then inoculated as desired. The flasks used have been made chemically clean by boiling with potassium permanganate, and the water used has been twice distilled. The other rigid precautions absolutely necessary in all work of this character have always been taken. The solutions thus prepared have contained from .0001 to .0010 parts per 100,000 of albuminoid ammonia.

Proceeding with this solution by the method of dilution, we at length succeeded in isolating a nitrifying organism. A flask was first inoculated with a few grains of sand from Tank No. 13, at the Lawrence Experiment Station, and when nitrification was at its height in this solution, a small portion was transferred from this to a second flask, and so on. After a large number of unsuccessful attempts, two solutions were finally obtained which nitrified well, but gave no growth upon ordinary gelatine plate cultures, although the plates were allowed to stand for seven days. Microscopic examination of these solutions showed them to be inhabited by a particular form of bacillus, and apparently by that alone. These bacilli are short, of a slightly oval shape, and vary from 1.1 μ to 1.7 μ in length; they are about .8 μ to .9 μ broad. They are grouped very characteristically in irregular clumps, and are held together by a jelly-like material. Each aggregation is indeed a typical zoöglœa. The aggregations of bacteria were found chiefly on the bottom of the flasks, as was also the case with the organism described by Winogradsky. These masses of zoöglœa, obtained as a pure culture from a nitrifying solution, resemble significantly the zoöglœa discharged in considerable quantities from the filter tanks at Lawrence. The bacilli stain with some difficulty with the usual aniline dyes. We have not observed independent movement. Owing to the lack of the usual means of diagnosis, it is difficult to determine in a short time whether this species is the same as the one described by the Franklands and by Winogradsky. On one important point there appears to be a difference between our results and those reached by the above-mentioned investigators. The organism discovered by them oxidizes ammonia to nitrite, but carries it no further. Our own flasks give complete oxidation to nitrate. Whether this be due to a difference of conditions, a difference in the virility of the organisms, or a specific difference in the bacteria, we are not at present prepared to say. The short time at our disposal has made it impossible to settle this and many other questions to our own satisfaction. We are not even prepared to say that there may not have been a mixture of two or more species in our flasks, all agreeing closely in morphological characters, and in giving no growth on gelatine, but differing in important physiological respects. Further investigation is necessary to settle this and other important points regarding the relations of this organism to the process of nitrification.

Whether or not we accept the views of Winogradsky, it is certainly worthy of remark, as he observes, that an organism should exist, which, without chlorophyll and in the apparent absence of organic nitrogen and of organic carbon, should be able to multiply and thrive upon wholly inorganic compounds. It may be well doubted, we think, whether this is really the case. It seems more reasonable to suppose that exceedingly minute quantities of organic nitrogen and carbon are actually present, and escape detection by our present methods of chemical analysis, although in reality sufficient to nourish generations of bacteria.

Our own experience, as well as that of previous investigators, seems to be a warning against a too confiding use of the gelatine plate culture in bacteriological work, since in this instance such confidence has left us for a long time in ignorance of a common and widespread as well as highly important organism.

THE PARASITE OF QUARTAN AGUE.

IN the *Zeitschrift für Hygiene* (x. 137) appears the first of a series of papers by Camillo Golgi, demonstrating by means of photography the development of the parasite found in malarious fevers. This paper, of which an abstract appears in the *British Medical Journal*, deals with the *amœba malariæ febris quartanæ*, the form found in the quartan type. In 1880 Laveran stated that these parasites are present in every case of malaria, and in no other condition, and that they are probably the cause of the disease. His observations have been confirmed by pathologists in all parts of the world, and at the present time the weight of proof seems to be in favor of his contention. In his paper Golgi claims to have been the first to demonstrate that the different forms described as occurring in the blood are simply modifications of one form, and, further, that these metamorphoses follow each other according to a fixed law. This development takes place within, and leads to the destruction of the red blood corpuscles.

At first the amœba-like parasite is small and non-pigmented; it increases in size at the expense of the substance of the blood corpuscles, becomes pigmented, and, after passing through a series of metamorphoses, finally ends in a process of segmentation. This process of segmentation takes place at the same time as, or a short time before, the onset of the febrile paroxysm, and has for its object the formation of a new generation of the parasites. The pigment granules stored up in the body of the parasite take no part in this process of segmentation, and hence, on its completion, escape into the blood plasma, where they are seized upon by the white blood corpuscles and cells of the liver, spleen, etc.

The new brood of parasites at once pass into fresh red blood corpuscles, and so commences anew the cycle of metamorphoses leading up to the next paroxysm of fever. The period of time which elapses between the entrance of the parasites into the red blood corpuscles and their segmentation is exactly three days, and hence arises the periodicity of the quartan type of malarial fever. During the first and second days the parasite passes through the various phases of its development within the blood corpuscles, on the third day segmentation takes place, the new brood is set free and fever results; in other words, the period of apyrexia corresponds with the endoglobular growth of the parasite.

Golgi states that a knowledge of these developmental stages is of immense practical importance for the purpose of diagnosis, by which an almost mathematical degree of accuracy can be arrived at, and that it is no exaggeration to say that by the simple microscopic examination of a few preparations of blood the physician is in a position to tell when the last attack of fever occurred, to foretell the time of the next attack, and further, to recognize what type of malarial fever he is dealing with. The simple quartan fever is explained by Golgi as resulting from the development the blood of one set of the parasites, which ripen every three days, while the double and triple quartan fevers are caused by the

development of two and three sets respectively, coming to maturity on consecutive days. This hypothesis, of course, cannot apply to the tertian type of malarious fever, since in this the febrile paroxysms follow each other with an interval of only one day of apyrexia intervening, instead of two days as in the case of the quartan type.

Golgi is of the opinion that he has brought forward satisfactory evidence to show that tertian ague depends on the presence in the blood of a distinct variety of the malaria parasite, which passes through its developmental phases in two days instead of in three. In regard to classification, Golgi holds that the various clinical types of intermittent fever are caused by varieties of one and the same parasitic species, and that this belongs to the genus amœba. The twelve photographs which illustrate his first paper deal with the development of the parasite of quartan fever, and show, surrounded by normal red blood corpuscles, its successive metamorphoses. The photographs, which are very fine, were taken by means of Zeiss's microphotographic apparatus.

LETTERS TO THE EDITOR.

On some Extinct Vertebrata from the Miocene Rocks of the North-west Territories of Canada recently described by Professor Cope.

AMONG the more recent and interesting additions to the collections in the National Museum, Ottawa, Canada, are the mammalian and fish remains from the tertiary rocks of the Canadian North-west. These collections which were made by Messrs. McConnell and Weston especially have been recently studied by Professor E. D. Cope of the Academy of Natural Sciences, Philadelphia. The results of his observations will soon be made known in a memoir now in print, and to be published by the Geological Survey Department. The specimens in question are now on exhibition in the upright cases of the museum, and from the labels attached the following interesting forms are noticed as of special interest.

Extinct Rhinoceros (*Menodus angustigenis*). — This is the name which Professor Cope has given to the largest species of hoofed animal analogous to the rhinoceros that has ever yet been discovered, and which in early tertiary times was roaming in the then existing forests of the now treeless prairie regions of Canada.

The best portion of the skull of one individual may be seen, about three feet long and eighteen inches across, with the frontal bones and snout preserved; also the two horn-cores and portions of the upper jaw, with several huge molars *in situ*. The lower jaw of the same individual was also found, and the teeth beautifully preserved. Some of these teeth are nearly four inches across and three inches in thickness, being nearly four inches in length, with zig-zag and sharply-cut crowns. The humerus, femur, tibia, many horn-cores, and bones of the pelvic arch and of various other portions of the skeleton, were also found, making in all a beautiful display of fossil bones belonging to as huge and ferocious a beast as prowls to-day in the jungles of an African or Indian forest. Besides this form of *Menodus*, Professor Cope has recognized a number of others, to which he has given separate specific designations, so we find that there existed in Canada not only this huge and ferocious species of *Menodus*, but other allied creatures. These include *Menodus syceras* Cope, *M. Proutii* Owen, *M. Americanus* Cope, and *M. Selwyni* Cope. They all belong to miocene tertiary strata occurring in the vicinity of Swift Current Creek, North-west Territory. These all belong to the family of the *Titanotheridæ*, and form a group of animals analogous to the rhinoceros.

Extinct Horse (*Anchitherium Westoni* Cope). — This is one of the forms which belong to the *Palæotheriidæ*, a family of extinct animals whose affinities seem to place them foremost as the ancestors of the *Equidæ* or horses.

Extinct Boar (*Elotherium Mortoni* Leidy). — Among the specimens on exhibition and collected by Mr. Weston may be seen an almost perfect lower left ramus of this extinct mammal, allied to the modern wild boar and pig, and belonging to the family of the *Chœropotamidæ*. This creature was of huge dimensions, the specimen of the jaw in question being nearly ten inches in length. The teeth are beautifully preserved in a spotted grey and yellow-white lime-rock. This is the first time that this form has been found so far north on the American continent.

Extinct Deer (*Leptomeryx mammifer* Cope).— This new species, a member of the family of the *Tragulidæ*, appears to be one of the ancestors of the deer tribe, being both a ruminant and ungulate mammal. A very well preserved portion of the lower jaw, with several teeth *in situ*, has permitted Professor Cope to establish its relations and affinities, and it forms a valuable addition to the fauna of those times which preceded the advent of the great ice age, when all these types disappeared and made room for the mastodon, the mammoth, and other creatures, including the megalonyx and its allies.

Other Extinct Forms.— Besides the above may be seen a large incisor belonging to a large *carnivore* allied to the modern dog or wolf; the tooth of an oreodont, an extinct hare (*Palæolagus turgidus* Cope) belonging to the family of the *Leporidæ;* also a species of *Trionyx* which Professor Cope has called *Trionyx leucopotamicus*, from the fact that similar forms occur also in the White River series of formations in the southern territories of the United States. But besides the above we find also extinct forms allied to the squirrels (*Hypertragulus riversus* Cope), and also a large number of bones of siluroid fishes belonging to the genera *Amiurus, Rhineastes*, etc. Among these we find *Amiurus McConnelli, A. cancellatus* (all described by Cope); also *Amia macrospondyla, Amia Selwyniana*, and *Rhineastes rhœas* Cope.

Fossil Turtles. — Then come the remains of a species of *Stylemys*, an extinct turtle belonging to the family of the *Testudinidæ*, one of the *Chelonia.*

Chalicotherium and *Hempisalodon.*— The latter form (described under the name of *H. grandis* Cope) affords another example of an extinct type of hyena, much larger than any of the modern living ones. It belongs to the family of the *Hyœnodontidæ*, and forms a part of a sub-order of that family with very large representatives. The genus *Chalicotherium*, one of the family of the *Chalicotheriidæ* Lydekker, has certain affinities to the rhinoceros, whose size and proportions it greatly resembled.

Thus it will be seen that from the miocene tertiary strata of the Swift Current River, not far from the line of the Canadian Pacific Railway, along the treeless prairie region of Canada, a large fauna existed, some of whose remains now adorn the cases of the National Museum at Ottawa.

HENRY M. AMI.

Ottawa, Ont., July 6.

Osteological Notes.

AMONG the primates, the *Anthropomorpha* (higher apes) have strong jugal arches, longer than in man, and presenting marked horizontal and vertical curvature. Although properly composed of only two bones, viz., the zygomatic process of the squamosal, and the jugal, this last rests upon a process of the maxilla so much developed that in many cases it might be rightfully considered as entering into the formation of the arch. The suture which joins the squamosal and the jugal is long and serrated, its great inclination downwards and backwards vastly increasing the strength of the parts as well as the power of resistance.

In the gorilla the jugal arch is relatively broader and more developed than in the other higher apes. The process of the squamosal presents a sudden vertical convexity upon its upper border, at a point corresponding to the junction of the anterior transverse root, the remaining portion of the arch being nearly of the same width. The breadth of the channel for the play of the temporal muscle is proportionally large. The entire structure of the arch, especially in its horizontal and vertical curvatures, exhibits enormous strength. In the adult male all the cranial ridges attain their maximum size, thus presenting a largely increased surface for the origin of the temporal muscle, while the relative greater breadth of the ascending ramus of the mandible, and the increased width of the pterygoid fossæ are correlated with a corresponding development of the masseter and pterygoid. The long and massive canines so characteristic of the higher apes, especially of the gorilla and orang, have reference to the powerful action of the last-named muscles. Their use has also a sexual relation. The glenoid cavity is transversely broader than in man, and

more shallow, its anterior boundary, formed by the inferior root of the zygoma, being scarcely developed, allowing greater freedom for the antero-posterior movement of the articulation of the mandible.

In comparing the skull of the male gorilla with that of man, — a male negro, for example, — we shall find the jugal arch of the former to be built upon a vastly stronger plan, both the squamosal and the malar presenting different forms and proportions. The squamosal is as long and vertically as wide as the malar portion of the arch, while its upper border rises into an angular form, constituting a very marked convexity, no trace of which is to be seen in the negro. In the latter the jugal portion of the arch decreases in depth after leaving the body of the bone, whereas in the gorilla it continues of the same depth and is also longer.

In the orang, the horizontal curvature of the arch is greatly produced, and strongly developed at the portion corresponding to the malar-squamosal suture. Its inferior border is flattened and thickened. The vertical curvature, however, is not so great, while the channel for the temporal muscle is relatively wider than it is in the gorilla. The crests and ridges of the cranium, especially in the male, express the great energy of this muscle, although the general outline of the arch is far less massive than in the latter ape.

The jugal arch of the chimpanzee's cranium presents much resemblance to that of man, being narrow, and with slight curvature either horizontal or vertical. The malar is anteriorly flatter, and its orbital process is longer and narrower at its base. The extent of surface for the development of the temporal muscle is greater than in man, and the width of the channel relatively increased.

The slight modifications observed in the jugal arch of the gibbons (*Hylobates*) exhibit a distinct tendency to those shown in the lower type of the *Simiana*, the monkeys. In these last, the old-world monkeys (*Catarrhinæ*), the arch takes on a sigmoidal curvature, thus presenting upon its superior border a slight convexity behind and a corresponding concavity anteriorly. The extent of this curvature varies in different groups. In the new-world monkey (*Platarrhinæ*) the post glenoid process of the squamosal is largely increased, while the remarkable extent of the ascending portion of the ramus, both vertical and antero-posterior, has reference to the great development of the vocal organs in the howling monkeys (*Mycetes*) rather than to any unusual energy of the masticatory muscles.

In the *Lemuroidea*, the family of the common lemurs (*Lemurinæ*) have an arch which in most cases is nearly straight, narrow, long, and distinguished by a malar-squamosal suture which is almost horizontal in direction, the amount of the overlapping of the jugal by the lengthened process of the squamosal being exceptional, while in some cases the jugal is partially underlapped by a process from the maxillary.

In studying the significance of the jugal arch as presented in the primates, although the modifications exhibited in some groups

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CARHART, H. A. Primary Batteries. Boston, Allyn and Bacon. 193 p. 12°. $1.50.
DRAYTON, H. S. Vacation Time, with Hints on Summer Living. New York, Fowler & Wells Co. 84 p. 12°. 25 cents.
GUYAU, J. M. Education and Heredity. (Contemporary Science Series.) New York, Scribner's. 306 p. 12°. $1.25.
MARILAUN, A. K. v. Algemeine Naturkunde. Lief. 124-129. Pflanzenleben, II. heft. 7-12. Leipzig, Bibliog. Institute. 336 p. 4°. (New York, Westermann.)
MERCANTILE Journal, the. Vol. I., No. 1. *w.* Chicago, J. A. Brewer & Co. 8 p. f°. $3 a year.
PILSBRY, H. A. Sea Shells of the Jersey Shore. Asbury Park, N. J., A. P. Novelty Co. 40 p. 16°.
ROYAL Society of Canada. Proceedings and Transactions of the, for the year 1890. Vol. VIII. Montreal, Dawson Bros. 632 p. 4°.

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of the order cannot readily be explained, the principal laws which govern its morphology, and which have been noted in previous papers, are sufficiently evident. These are, that the development of the arch, as shown by the number of bones, by the degree and form of its curvature, by its relation to the orbit and articulation of the mandible, as well as to other neighboring parts, and the amount of surface presented for muscular development, are correlated with the energy of the masticatory power, joined in some of the higher apes with a prehensile strength of jaws and dental series eminently characteristic of their ferocity.

D. D. SLADE.

Cambridge, Mass., July 11.

AMONG THE PUBLISHERS.

THE J. B. Lippincott Company, Philadelphia, have in press, and will publish early in the fall, "A Supplement to Allibone's Critical Dictionary of English Literature and British and American Authors," by John Foster Kirk. The work contains over thirty-seven thousand articles (authors), and enumerates over ninety-three thousand titles. It will be published in two volumes, large 8vo size, and will comprise about sixteen hundred pages.

— *The Chautauquan* for August presents the following among other articles: "Flying by Means of Electricity," by Professor John Trowbridge; "What Shall be Taxed?" by Edward W. Bemis; "African Myths and Legends," by Heli Chatelain; "The Physical and the Mental in Hypnotism," by Alfred Fouillée; "Death Valley," by R. S. Dix; "Travelling in Provincial France," by Elizabeth Robins Pennell; "England in the Eighteenth Century," by Edward A. Freeman; "The Spell of the Past," by John Burroughs; "Modern Surgery," by C. R. Hammerton; "The Sorosis Club at Bombay, India," by Mrs. M. B. Denning; "A Colored Creole Type," by Julie Wetherill Baker; "What Women's Clubs have done for Women," by Mrs Kate Tannatt Woods; and "A Town Minus Poverty," by Clare De Graffenried.

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